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Lawrence Berkeley National Laboratory Report

ASHRAE 110 Tracer Gas Containment Test
Prototype Berkeley hood;
"Final" Configuration

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ASHRAE 110 Tracer Gas Containment Test

Conducted at Lawrence Berkeley National Laboratory

Overview

The ASHRAE Standard, ANSI/ASHRAE 110- 1995, *Method of Testing Performance of Laboratory Fume Hoods*, is the foremost protocol used when testing laboratory-type fume hood performance. The ASHRAE-110 "Method" is an elaborate, three-part test that involves face velocity testing, flow visualization, and a tracer gas test. Refer to ANSI/ASHRAE 110-1995 for specific information regarding its Purpose (Section 1), Scope (Section 2), Definitions (Section 3), Instrumentation and Equipment (Section 4), and Test Conditions (Section 5). The tests, referenced below, used the ASHRAE 110 method's Section 6.1, Flow Visualization and Section 7 (7.1 through 7.10), Tracer Gas Testing Procedure to evaluate containment performance.

An Innovative Laboratory-type hood

Researchers at Lawrence Berkeley National Laboratory (LBNL) are developing an innovative containment technology that reduces required airflow through laboratory fume hoods. This technology provides containment at 50 to 70 percent lower airflow than a typical fume hood, based on total exhaust volume. It does not rely on face velocity, in the traditional sense, to maintain fume containment within a hood. Therefore, ASHRAE 110 face velocity tests were not performed (Section 6.2, Face Velocity Measurements).

The LBNL containment technology uses a "push-pull" displacement airflow approach to contain fumes and move air through a hood. Displacement air "push" is introduced with supply vents near the hood's sash opening. Displacement air "pull" is provided by simultaneously exhausting air from the hood. Thus, an "air divider" is created, between an operator and a hood's contents, that separates and distributes airflow at the sash opening. This air divider technology is simple, protects an operator, and delivers dramatic cost reductions in a facility's construction and operation.

Evolution of the Berkeley hood

Dr. Helmut Feustel, a LBNL staff researcher, developed basic concepts for a High-Performance Laboratory Fume Hood during 1995–1998. This High-Performance Laboratory Fume Hood is referred to, in this document, as the “Berkeley hood.” In January 1999, LBNL's Environmental Energy Technologies Division (EETD) transferred the project to its Applications Team. At this time, the research project team developed a "prototype" Berkeley hood.

"Final" Prototype Berkeley hood

The prototype hood was built with a superstructure provided by Labconco. By August 2000, it was modified and evaluated extensively over a period of nearly two years before this series of containment tests was performed. This incarnation represents the "final" Berkeley hood configuration (LPx) both dimensionally and functionally. Figure 1, below, is the “Final” Berkeley hood prototype, as tested.

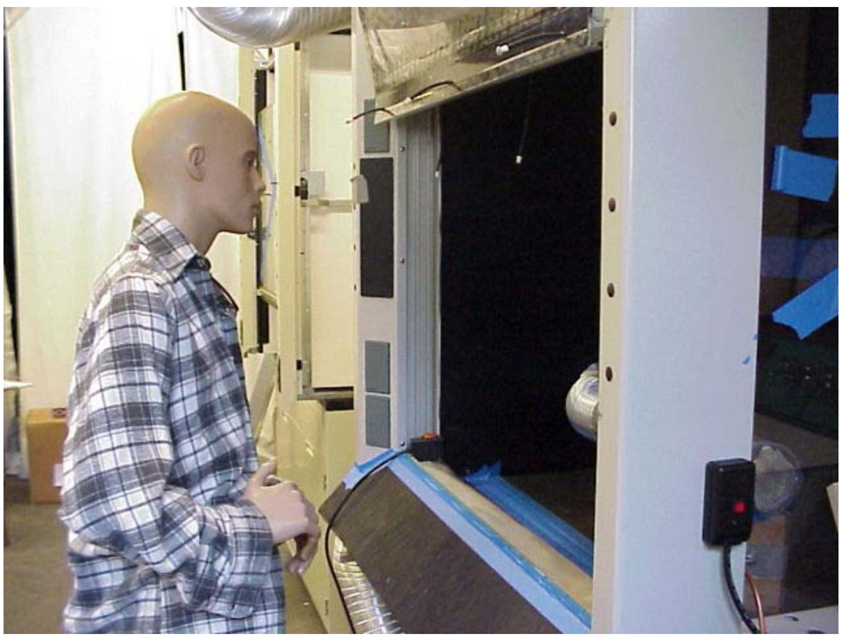


Figure 1: Final Berkeley hood Prototype

Next version of the Berkeley hood

Evolved design information, included in the final prototype, was transferred to Labconco. They are proceeding to build an "alpha" version of the Berkeley hood for a demonstration project to be conducted at the University of California, San Francisco (UCSF). [Containment test results from this “alpha” hood are presented in LBNL report, LBNL-50070.]

Containment Tests and Setup

Description of Test Procedure

As noted above, LBNL researchers successfully applied two of ASHRAE's 110-1995 test methods, flow visualization and tracer gas tests, Section 6.1 and Section 7, respectively. A general overview of these two tests is provided:

1) Flow visualization tests can be performed with various smoke-generating substances. Theatrical smoke, superheated glycol, smoke "sticks", titanium tetrachloride, and dry ice, solid-phase CO2, are examples of smoke sources. A qualitative understanding of containment is gained from conducting smoke tests. A rating system has been devised for "poor- to-good" patterns of smoke containment by Tom Smith[1]. However, these tests are only used as indicators of containment. When satisfactory results are observed, they should be followed by tracer gas testing.

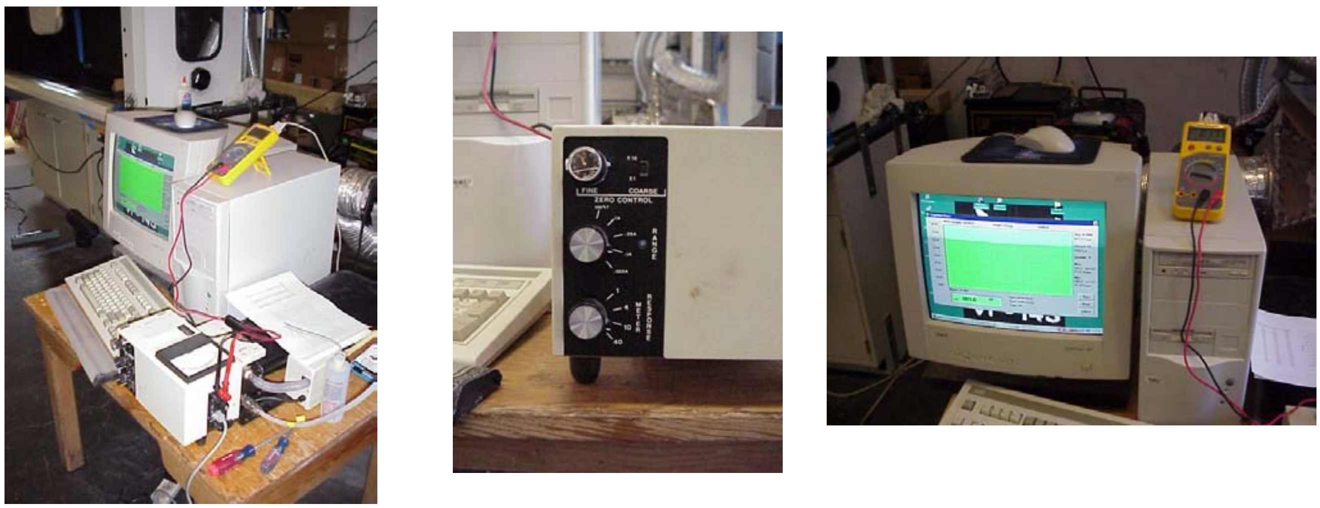
2) Tracer gas testing is the most reliable test for determining a fume hood's containment performance. A highly generalized overview of the test is provided. The gas most typically used is sulfur hexafluoride, or SF6. This gas flows into a fume hood being tested through a specially constructed "ejector." The ASHRAE 110 guideline includes engineering drawings to fabricate this ejector. SF6 flow rate is set at four liters per minute. The ejector is placed in different positions (center, left, and right) in the hood. A mannequin is placed in front of the hood being tested to simulate an operator. An inlet port to a detector device is placed at the "breathing zone" (the nose) of the mannequin. Tracer gas is allowed to flow for five minutes and spillage levels are recorded by the detector. Ratings can be provided for a hood at three levels of installation:

   - "As manufactured" (AM) — initial test of performance in a highly controlled/idealized setting at the manufacturer's facility.
   - "As installed" (AI) — testing is completed in the actual, fully operating facility, with more challenging conditions than the manufacturers' facility.
   - "As used" (AU) — testing is performed by adding a hood operator's experimental equipment, a.k.a., "clutter", to the "as installed" hood, making the test conditions even more difficult.

[1] Tom Smith, President of Exposure Control Technologies, Inc. 231-C East Johnson St. Cary, NC 27513 ph: 919.319.4290

Test Instrumentation

The test instrument used to detect SF6 was a Foxboro Miran 1A without an inlet filter. Its inlet tube was located at nose of a mannequin. The Miran 1A was calibrated with known sources of SF6 in "cal bags." (A conversion factor of 0.110 PPM was equal to 0.055 volts; therefore, the concentration was equal to two times voltage indicate by a VOM.) Figures 2,3, and 4, below, are of Miran 1A test setup.



Figures 2, 3, and 4: Foxboro Miran 1A apparatus and data

Acceptability Level

Testing criterion used is from ANSI/AIHA Standard Z9.5 (1992) for the "as installed" designation for the situation in the test/fabrication laboratory. The acceptability level required for AI designation is 0.1 PPM or less for five minute average at three mannequin positions; left, center, and right. Note that the more stringent "as manufactured" designation was also noted in test results. In this case, AM designation is 0.05 PPM or less for five minute average at three mannequin positions.

Deviations from ASHRAE 110 Containment Test Procedure

Face velocity tests (Section 6.2) and Variable Volume Tests (Sections 6.3 and 6.4) were not performed. Periphery tracer-gas test (Section 7.11) and sash movement effect (Section 7.12) were not performed.

Exception Report

The tracer gas test in the left side of hood had the mannequin's arms inserted into the hood's sash opening, making this a more challenging (and non-standard) test.

Containment Test Airflows

Exhaust Airflow Rate

In a “conventional” hood, exhaust airflow rate is attained by flowing air at an average value of 100 FPM through the open sash area (a.k.a. face velocity). The open sash area of the Berkeley hood is equal to 7.76 square feet. Therefore, at a “conventional” face velocity of 100 FPM, this would require an exhaust airflow of 776 CFM through the hood. However, the Berkeley hood was operated and tested at an exhaust rate of 313 CFM, which is 40 percent of conventional hood. Initially, the hood’s exhaust airflow was determined with a calibrated fan to generate a system pressure-drop curve. Subsequent airflow measurements were determined by using a pitot tube (in the hood’s exhaust stack) and differential pressure meter with this system pressure-drop curve.

Supply Airflow Rate

Supply flows were set at the values listed below. Airflow rates were determined by measuring the pressure drop at a "critical orifice" with a differential pressure meter. A critical orifice is a device for maintaining a consistent, predictable pressure drop, at specific flow-rates, through a sampling instrument. In addition, airflow velocity from supply grill/screens were also measured with hot wire anemometer (values presented in parentheses):

1) Top Plenum: 73 to 75 CFM (average 70 FPM screen velocity).

2) Front Plenum: 63 to 67 CFM (average 70 FPM screen velocity).

3) Lower (bottom) Plenum: 96 to 97 CFM (average 70 FPM grill velocity).

Containment Test Results

Summary of Results

As noted, the prototype hood passed in all tests performed. Again, note that tracer gas test in left side of hood had the mannequin's arms inserted into the hood's sash opening making this a more challenging, non-standard test. Containment PPM is provide in the form (see Section 3, Definitions) of 4.0-AI-xxx, where xxx is the average PPM measured. ANSI Z9.5-1992 recommendations provide a "pass" rating when this containment value is 4.0-AI-0.1 or less.

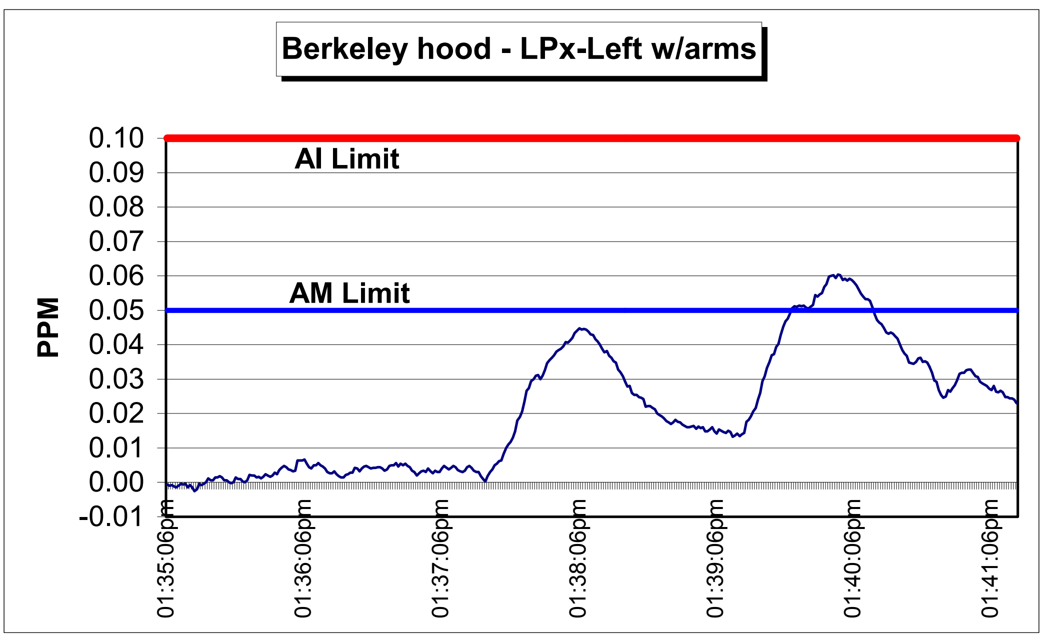
Test Type	Total	Containment	Aver. PPM	Max. PPM
Smoke – Large Volume	40%	Good	NA	NA
Smoke – Small Volume Edge	40%	Good	NA	NA
Tracer Gas – SF6 – Left (w/arms)	40%	Pass	0.021	0.060
Tracer Gas – SF6 – Center	40%	Pass	0.008	0.020
Tracer Gas – SF6 – Right	40%	Pass	0.003	0.010

*Total Exhaust based on standard hood flowing at 100 FPM face velocity through the open sash area. Open sash area Berkeley Alpha hood is equal to 7.76 square feet x 100 FPM = 776 CFM. Hood was flowing at 313 CFM; therefore, 40 percent of standard hood.

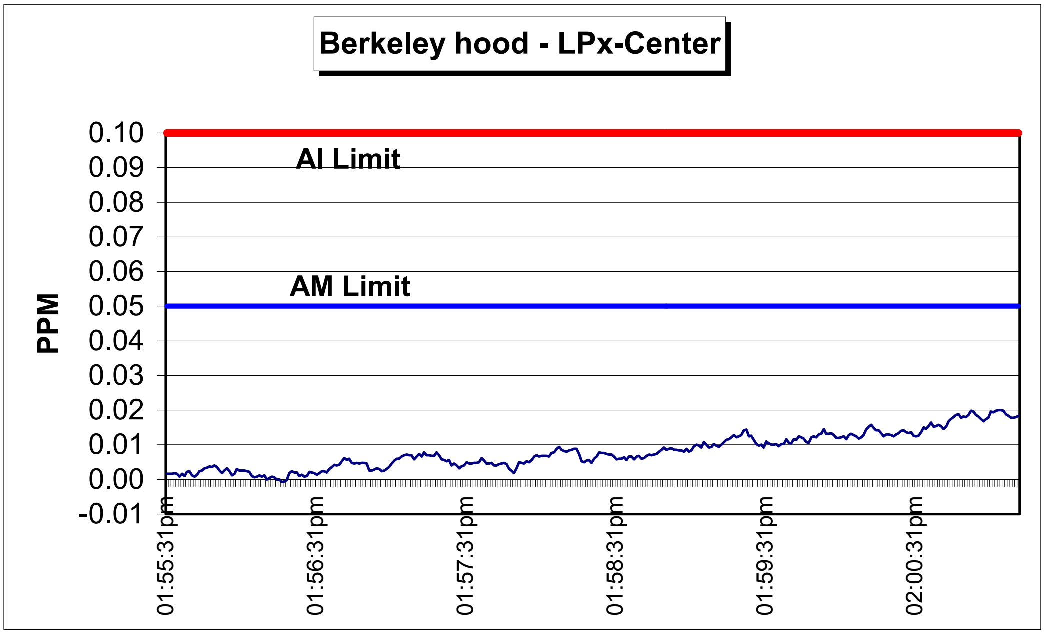
Containment Test Plots

The following are plots of the three SF6 tracer gas test runs that lasted for five minutes. Note that the more demanding designation of AM is accomplished in each test run, on average, with the added challenge of inserting the mannequin's arms into the hood.

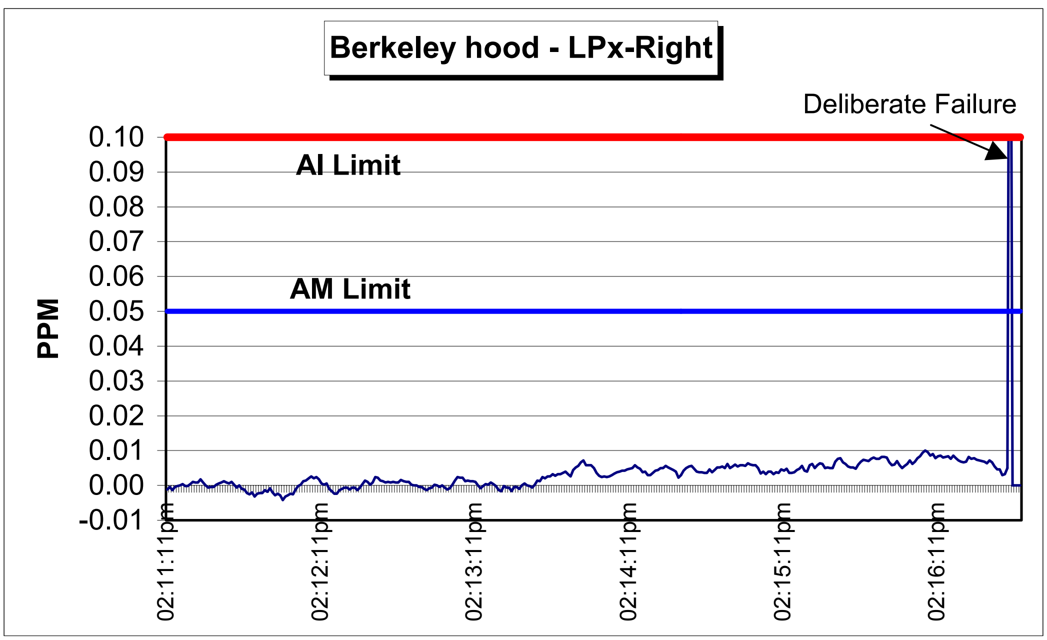
Plot 1



Plot 2


Berkeley hood - LPx-Center
PPM
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
AI Limit
AM Limit
01:55:31pm
01:56:31pm
01:57:31pm
01:58:31pm
01:59:31pm
02:00:31pm

Plot 3


Berkeley hood - LPx-Right
Deliberate Failure
PPM
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
AI Limit
AM Limit
02:11:11pm
02:12:11pm
02:13:11pm
02:14:11pm
02:15:11pm
02:16:11pm